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The Medawar Lecture 1998 Is science dangerous?

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The idea that science is dangerous is deeply embedded in our culture, particularly in literature, yet science provides the best way of understanding the world. Science is not the same as technology. In contrast to technology, reliable scientific knowledge is value-free and has no moral or ethical value. Scientists are not responsible for the technological applications of science; the very nature of science is that it is not possible to predict what will be discovered or how these discoveries could be applied. The obligation of scientists is to make public both any social implications of their work and its technological applications. A rare case of immoral science was eugenics. The image of Frankenstein has been turned by the media into genetic pornography, but neither cloning nor stem cells or gene therapy raise new ethical issues. There are no areas of research that are so socially sensitive that research into them should be proscribed. We have to rely on the many institutions of a democratic society: parliament, a free and vigorous press, affected groups and the scientists themselves. That is why programmes for the public understanding of science are so important. Alas, we still do not know how best to do this.

Keywords: genes; technology; trust; bioethics; social responsibility; public understanding

1. INTRODUCTION

The idea that scientific knowledge is dangerous is deeply embedded in our culture. Adam and Eve were forbidden to eat from the Tree of Knowledge, and in Milton's *Paradise Lost* the serpent addresses the Tree as the 'Mother of Science'. Moreover, the archangel Raphael advises Adam to be lowly wise when he tries to question him about the nature of the universe. Indeed, the whole of Western literature has not been kind to scientists and is filled with images of scientists meddling with nature with disastrous results. Also, there is a persistent image of scientists as a soulless group of males who can do damage to our world.

Just consider Shelley's *Frankenstein*, Goethe's *Faust* and Huxley's *Brave New World*. One will search with very little success for a novel in which scientists come out well. And where is there a film sympathetic to science?

There is a fear and distrust of science: genetic engineering and the supposed ethical issues it raises, the effect of science in diminishing our spiritual values—even though many scientists are themselves religious, the fear of nuclear weapons and nuclear power, the impact of industry in despoiling the environment. There is something of a revulsion in humankind's meddling with nature and a longing for a golden Rousseau-like return to an age of innocence. There is anxiety that scientists lack both wisdom and social responsibility and are so motivated by ambition that they will follow their research anywhere, no matter the consequences. Scientists are repeatedly referred to as 'playing at God'. Many of these criticisms coexist with the hope, particularly in medicine, that science will provide cures to all major illnesses, such as cancer, heart disease and genetic disabilities like cystic fibrosis. But is science dangerous and what are the special social responsibilities of scientists?

It is worth noting from the start one irony; while scientists are blamed for despoiling the environment and making us live in a high risk society, it is only because of science that we know about these risks, such as global warming and bovine spongiform encephalopathy (BSE).

The media must bear much of the responsibility for the misunderstanding of genetics as genetic pornography which is, unfortunately, widespread—pictures and stories that titillate. A recently widely publicized picture of a human ear on the back of a mouse is a nice, or rather a nasty, example. This was just ear-shaped cartilage stuck under the skin for no obvious scientific reason—not an ear at all. Images of the phoney ear, which many find distasteful, are linked to an effluvium of headlines like 'Monsters or Miracles?' and phrases like 'moral nightmare'. This genetic pornography does, however, sell newspapers, and exploiting people's anxieties attracts large audiences. It is also a distraction from the real problems in our society.

Yet science provides the best way of understanding the world in a reliable, logical, quantitative, testable and elegant manner. Science is at the core of our culture, almost the main mode of thought that characterizes our age. But, for many people, science is something rather remote and often difficult. Part of the problem is that almost all scientific explanations go against common sense, our natural expectations, for the world is just not built on a common sense basis (Wolpert 1992). It is quite unnatural to think of the Earth moving round the sun, to take a very

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simple example, but there are many similar ideas that we now generally accept, such as force causing acceleration, not motion, and the very idea of Darwinian evolution, that we humans came from random changes and selection.

2. TECHNOLOGY

A serious problem is the conflation of science and technology. The distinction between science and technology, between knowledge and understanding on the one hand, and the application of that knowledge to making something, or using it in some practical way, is fundamental. Science produces ideas about how the world works, whereas the ideas in technology result in usable objects. Technology is much older than anything one could regard as science and unaided by any science, technology gave rise to the crafts of early humans, like agriculture and metalworking. Science made virtually no contribution to technology until the nineteenth century (Basalla 1988). Even the great triumphs of engineering like the steam engine and Renaissance cathedrals were built without virtually any impact of science. It was imaginative trial and error and they made use of the five minute theorem—if, when the supports were removed, the building stood for five minutes, it was assumed that it would last forever. Galileo made it clear that the invention of the telescope was by chance and not based on science.

But it is technology that generates ethical issues, from motor cars to cloning a human. Much modern technology is now founded on fundamental science. However, the relationship between science, innovation and technology is complex. Basic scientific research is driven by academic curiosity and the simple linear model which suggests that scientific discoveries are then put into practice by engineers is just wrong. There is no simple route from science to new technology. Moreover, marketing and business skills are as important as those of science and engineering and scientists rarely have the money or power to put their ideas into practice.

In contrast to technology, reliable scientific knowledge is value-free and has no moral or ethical value. Science tells us how the world is. That we are not at the centre of the universe is neither good nor bad, nor is the possibility that genes can influence our intelligence or our behaviour. Dangers and ethical issues only arise when science is applied in technology. However, ethical issues can arise in actually doing the scientific research, such as carrying out experiments on humans or animals, as well as issues related to safety, as in genetically modified (GM) foods. There are now claims that the techniques used in nanotechnology may release dangerous chemical compounds into the environment.

3. SOCIAL RESPONSIBILITY

Are scientists in favour of the technological applications of science? In a recent issue of the journal *Science*, the 1995 Nobel Peace Prize laureate, Sir Joseph Rotblat, proposed a Hippocratic oath for scientists. He is strongly opposed to the idea that science is neutral and that scientists are not to be blamed for its misapplication. Therefore, he proposes an oath, or pledge, initiated by the Pugwash Group in the USA. 'I promise to work for a better world, where science and technology are used in socially responsible ways. I will not use my education for any purpose intended to harm human beings or the environment. Throughout my career, I will consider the ethical implications of my work before I take action. While the demands placed upon me might be great, I sign this declaration because I recognize that individual responsibility is the first step on the path to peace.'

These are indeed noble aims to which all citizens should wish to subscribe, but it does present some severe difficulties in relation to science. Rotblat does not want to distinguish between scientific knowledge and its applications, but the very nature of science is that it is not possible to predict what will be discovered or how these discoveries could be applied. Cloning provides a good example of this. The original studies related to cloning were largely the work of biologists in the 1960s. They were studying how frog embryos develop and wanted to find out if genes, which are located in the cell nucleus, were lost or permanently turned off as the embryo developed. It was incidental to the experiment that the frog that developed was a clone of the animal from which the nucleus was obtained. The history of science is filled with such examples. The poet Paul Valery's remark that 'We enter the future backwards' is very apposite in relation to the possible applications of science. Scientists cannot easily predict the social and technological implications of their current research. It was originally argued that radio waves would have no practical applications, and Lord Rutherford said that the idea of applying atomic energy was 'moonshine'. It was this remark that sparked Leo Szilard to think of a nuclear reaction that led to the atom bomb (Rhodes 1986). There was, again, no way that those investigating the ability of certain bacteria to resist infection by viruses would lead to the discovery of restriction enzymes, an indispensable tool for cutting up DNA and the genetic material which is fundamental to genetic engineering.

The social obligations that scientists have as distinct from those responsibilities they share with all citizens, such as supporting a democratic society and taking due care of the rights of others, comes from them having access to specialized knowledge of how the world works that is not easily accessible to others. Their obligation is to both make public any social implications of their work and its technological applications and to give some assessment of its reliability. In most areas of science, it matters little to the public whether a particular theory is right or wrong, but in some areas, such as human and plant genetics, it matters a great deal. Whatever new technology is introduced, it is not for the scientists to make the moral or ethical decisions. They have neither special rights nor skills in areas involving moral or ethical issues. There is, in fact, a grave danger in asking scientists to be more socially responsible if that means that they have the right and power to take such decisions on their own. Moreover, scientists rarely have power in relation to applications of science; this rests with those with the funds and the government. The way scientific

knowledge is used raises ethical issues for everyone involved, not just scientists.

In relation to the building of the atomic bomb, the scientists behaved morally and fulfilled their social obligations by informing their governments about the implications of atomic theory. The decision to build the bomb was taken by politicians, not scientists. And it was an enormous engineering enterprise. Had the scientists decided not to participate in building an atomic weapon, that decision could have led to losing the war. Should scientists on their own ever be entitled to make such decisions? No! Scientists have an obligation to make the reliability of their ideas in such sensitive areas clear to the point of overcautiousness, and the public should be in a position to demand and critically evaluate the evidence. That is why programmes for the public understanding of science are so important.

4. EUGENICS

It is not easy to find examples of scientists as a group behaving immorally or in a dangerous manner—BSE is not an example—but the classic was the eugenics movement, which is the classic immoral tale of science. In 1883, Darwin's cousin, Francis Galton, coined the word from the Greek 'good in birth' (Kevles 1985). Eugenics was defined as the science of improving the human stock by giving 'the more suitable races or strains of blood a better chance of prevailing speedily over the less suitable.' Would it not, he conjectured, be 'quite practicable to produce a highly gifted race of men by judicious marriages during consecutive generations?' The scientific assumptions behind this proposal are crucial; the assumption is that most desirable and undesirable human attributes are inherited. Not only was talent perceived of as being inherited, but so too were pauperism, insanity and any kind of so-called feeblemindedness. The eugenicists considered many undesirable characteristics such as prostitution as being genetically determined. As Kevles points out in his book *In the Name of Eugenics*, the geneticists warmed to their newly acquired priestly role. Between 1907 and 1928 approximately 9000 people were sterilized in the USA on the general grounds that they were 'feebleminded'.

The ideas of eugenics received support from a wide group of both scientists and non-scientists. An American, Charles Davenport, was particularly influenced by the ideas of eugenics, and in 1904 he persuaded the Carnegie Foundation to set up the Cold Spring Harbor Laboratories in order to study human evolution. Davenport collected human pedigrees and came to believe that certain undesirable characteristics were associated with particular races; Negroes were inferior, Italians tended to commit crimes of personal violence and Poles were self-reliant, though clannish. He expected the American population to change through immigration and become 'darker in pigmentation, smaller in stature, more mercurial, more given to crimes of larceny, kidnapping, assault, incest, rape and sexual immorality'. He therefore proposed a programme of negative eugenics aimed at preventing proliferation of the bad. He favoured a selective immigration policy to prevent contamination of what he called the germ plasm—the genetic information parents transmitted to their offspring.

Davenport and his followers viewed genetics in terms of the action of a single gene, even though they knew that many characters are polygenic, that is, they are influenced by many genes. The eugenicists considered many undesirable characteristics such as prostitution as being genetically determined. The geneticists warmed to their newly acquired priestly role. The list of distinguished scientists that initially gave eugenics positive support is, depressingly, impressive enough.

In the 1930s, the geneticists, who included Huxley, Haldane, Hogben and Jennings, began to react and resist the wilder claims for eugenics. But it was too late, for the ideas had taken hold in Germany. As the geneticist Muller-Hill (1988) put it: 'The ideology of the National Socialists can be put very simply. They claimed that there is a biological basis for the diversity of mankind. What makes a Jew, a Gypsy, an asocial individual asocial and the mentality abnormal, is in their blood, that is to say in their genes'. And one can even detect such sentiments, regrettably, in the writings of the famous animal behaviourist, Konrad Lorenz: 'It must be the duty of social hygiene to be attentive to a more severe elimination of morally inferior human beings than is the case today' and then argued that asocial individuals have become so because of a defective contribution.

In 1933, Hitler's cabinet promulgated a eugenic sterilization law which made sterilization compulsory for anyone who suffered from a perceived hereditary weakness, including conditions that ranged from schizophrenia to blindness. This must rank as the outstanding example of the perversion of science. And it can also be regarded as leading directly to the atrocities carried out by doctors and others in the concentration camps.

With the somewhat smug wisdom of hindsight, we may think how misguided were many of the eugenicists. Many of the scientists may well have been honourable, and in some respects, good scientists. But they were bad scientists in terms of some of their genetics and more significantly, in relation to their social obligations. They could perhaps plead ignorance with respect to their emphasis on genes determining so many human characteristics, but they completely failed to give an assessment of the reliability of their ideas or to sufficiently consider their implications. Quite to the contrary, and even more blameworthy, their conclusions seem to have been driven by what they saw as the desirable social implications. The main lesson to be learned from the story of the eugenics movement is that scientists can abuse their role as providers and interpreters of complex and difficult phenomena. Scientific knowledge should be neutral, value-free. When mixed with a political or social aim it can be perverted.

Terrible crimes have been committed in the name of eugenics. Yet I am a eugenicist. For it now has another, very positive, side. Modern eugenics aims to both prevent and cure those with genetic disabilities. Recent advances in genetics and molecular biology offer the possibility of prenatal diagnosis and so parents can

choose whether or not to terminate a pregnancy. There are those who abhor abortion, but that is an issue that should be kept quite separate from discussions about genetics. In Cyprus, the Greek Orthodox Church has cooperated with clinical geneticists to dramatically reduce the number of children born with the crippling blood disease thalassemia. This must be a programme that we should all applaud and support. I find it hard to think of a sensible reason why anybody should be against curing those with genetic diseases such as muscular dystrophy and cystic fibrosis.

5. REPRODUCTION: CLONING, GENES AND STEM CELLS

Mary Shelley could be both proud and shocked. Her creation of a scientist creating and meddling with human life has become the most potent symbol of modern science. She could be shocked because her brilliant fantasy has become so distorted that even those who are normally quite sensible lose all sense when the idea of cloning humans appears before them.

Ironically, the real clone of sheep has been the media blindly and unthinkingly following each other—how embarrassed Dolly ought to be. The moral masturbators have been out in force telling us of the horrors of cloning. Jeremy Rifkin in the USA demanded a world wide ban and suggests that it should carry a penalty 'on a par with rape, child abuse and murder.' Many others, national leaders included, have joined in that chorus of horror. But what horrors? What ethical issues? In all the righteous indignation I have not found a single new relevant ethical issue spelled out.

It seems distasteful, but the 'yuuk' factor is, however, not a reliable basis for making judgments. There may be no genetic relation between a mother and a cloned child, but that is true of adoption and cases of *in vitro* fertilization (IVF). Identical twins who are a clone are not uncommon, and this upsets no one except the hard stressed parents. What fantasy is it that so upsets people? If, for example, one could clone Richard Dawkins, who seems to quite like the idea, how terrible would that be? While genes are very important, so is the environment, and since his whole upbringing would be completely different and he might even have a religious disposition—clones might make very rebellious children. Indeed the feelings that a cloned child might have about its individuality must be taken into account. However, this is an issue common to several other types of assisted reproduction such as surrogate mothers and anonymous sperm donors. I am totally against cloning as it carries a high risk of abnormalities as numerous scientific studies on other animals show. Those who propose to clone a human are medical technologists not scientists.

The really important issue is how the child will be cared for. Given the terrible things that humans are reported to do each other and even to children, cloning should take a very low priority in our list of anxieties. Or perhaps it is a way of displacing our real problems with unreal ones. Having a child raises real ethical problems as it is parents who play God, not scientists. Here lies a bitter irony. A parent's relation to a child is infinitely more God-like than anything that scientists may discover. Parents hold tremendous power over young children. They do not always exercise it to the child's benefit and there is evidence that as many as 10% of children in the UK suffer some sort of abuse.

Would one not rather accept 1000 abortions and the destruction of all unwanted frozen embryos than a single unwanted child who will be neglected or abused? I take the same view in regard to severely crippling and painful genetic diseases. On what ground should parents be allowed to have a severely disabled child when it could be relatively easily prevented by prenatal diagnosis? It is nothing to do with consumerism but the interests and rights of the child. The hostility to choosing a child's genetic make-up—designer babies—ignores the possibility that quite unsuitable parents can have children even if they are child abusers, drug addicts and suffering from disabling diseases like AIDS.

It is not, as the bio-moralists claim, that scientific innovation has outstripped our social and moral codes. Just the opposite is the case. Their obsession with the life of the embryo has deflected our attention away from the real issue, which is how the babies that are born are raised and nurtured. The ills in our society have nothing to do with assisting or preventing reproduction, but are profoundly affected by how children are treated. Children that are abused grow up to abuse others.

So what dangers does genetics pose? Bioethics is a growth industry, but one should regard the field with caution as the bioethicists have a vested interest in finding difficulties. Moreover, it is hard to see what contribution they have made. Some of these common fears are little more than science fiction at present, like cloning enormous numbers of genetically identical individuals. Who would the mothers be, and where would they go to school? In fact, it is quite amusing to observe the swing from moralists who deny that genes have an important effect on intelligence to saying that a cloned individual's behaviour will be entirely determined by the individual's genetic make-up.

It is all too easy to be misled as to what genes actually do for us. There is no gene, for example, for the eye; many hundreds, if not thousands, are involved, but a fault in just one can lead to major abnormalities. The language in which many of the effects of genes are described leads to confusion. No sensible person would say that the brakes of a car are for causing accidents. Yet, using a convenient way of speaking, there are numerous references to, for example, the gene for homosexuality or the gene for criminality. When the brakes of the car, which are there for safe driving, fail, then there is an accident. Similarly, if criminality has some genetic basis then it is not because there is a gene for criminality but because of a fault in the genetic complement, which has resulted in this particular undesirable effect. It could have affected how the brain developed—genes control development of every bit of our bodies or it could be owing to malfunction of the cells of the adult nerve cells.

A report by the Nuffield Council on Bioethics (1998) emphasizes that the whole human be viewed as a person, and in doing so may have neglected to explain just how genes affect all aspects of our life, not

least our behaviour. They thus have leaned somewhat towards a holistic anti-reductionist view of human psychology and made no attempt to respond to the anti-reductionist approach which even goes so far as to oppose genetic research into mental disorders. I would argue that all of science is essentially reductionist. In failing to make this clear they may have done bad service to genetics, developmental biology and neuroscience.

Gene therapy, introducing genes to cure a genetic disease such as cystic fibrosis, carries risks as does all new medical treatments. There may well be problems with insurance and testing but are these any different from those related to someone suspected of having AIDS? Anxieties about designer babies are at present premature as it is far too risky, and we may have, in the first instance, to accept what Dworkin (1993) has called procreative autonomy, a couple's right 'to control their own role in procreation unless the state has a compelling reason for denying them that control'. One must wonder why the bio-moralists do not devote their attention to other technical advances, such as that convenient form of transport which claims over 50 000 killed or seriously injured each year. Could it be that in this case they themselves would be inconvenienced? Applications of embryology and genetics, in striking contrast, have not harmed anyone.

Stem cells, cells that can give rise to a wide variety of different cell types, have the potential to alleviate many medical problems from damaged hearts to paralysis owing to damage to nerves. The best stem cells can be obtained from early embryos but as this causes the death of the embryo, there are those who oppose this method as they see the fertilized egg as already a human being. There is no justification for this view, as the early embryo can give rise to twins and so is not in any way an individual. Also, IVF involves the destruction of many embryos and one could oppose this very valuable treatment as well as getting embryonic stem cells, but ethically they are indistinguishable. The same is true for therapeutic cloning to make stem cells that would not be rejected by the immune system of the patient.

6. POLITICS

John Carey, a professor of English in Oxford, writes, 'The real antithesis of science seems to be not theology but politics. Whereas science is a sphere of knowledge and understanding, politics is a sphere of opinion.' (Carey, 1995) He goes on to point out that politics depends on rhetoric, opinion and conflict. It also aims to coerce people. Politics, I would add, is also about power and the ability to influence other people's lives. Science, ultimately, is about consensus as to how the world works and if the history of science were rerun, its course would be very different but the conclusions would be the same—water, for example, would be two hydrogens combined with one oxygen and DNA the genetic material, though the names would not be similar.

There are surveys that show some distrust of scientists, particularly those in government and industry. This probably relates to BSE and GM foods and so one must ask how this apparent distrust of science actually affects people's behaviour. I need to be persuaded that many of those who have this claimed distrust would refuse, if ill, to take a drug that had been made from a genetically modified plant, or would reject a tomato so modified that is was both cheap and would help prevent heart disease. Who refuses insulin or growth hormone because it is made in genetically modified bacteria? It is easy to be negative about science if it does not affect your actions.

No politician has publicly pointed out, or even understood, that the so-called ethical issues involved in therapeutic cloning are indistinguishable from those that are involved in IVF. One could even argue that IVF is less ethical than therapeutic cloning. But no reasonable person could possibly want to ban IVF, which has helped so many infertile couples. Where are the politicians who will stand up and say this? Genetically modified foods have raised extensive public concerns and there seems no alternative but to rely on regulatory bodies to assess their safety as they do with other foods and similar considerations apply to the release of genetically modified organisms. New medical treatments, requiring complex technology, cannot be given to all. There has to be some principle of rationing and this really does pose serious moral and ethical dilemmas much more worthy of consideration than the dangers posed by genetic engineering.

Are there areas of research that are so socially sensitive that research into them should be avoided, even proscribed? One possible area is that of the genetic basis of intelligence, and particularly, the possible link between race and intelligence. Are there then, as the literary critic George Steiner has argued, 'certain orders of truth which would infect the marrow of politics and would poison beyond all cure the already tense relations between social classes and these communities.' In short, are there doors immediately in front of current research which should be marked 'too dangerous to open'? I realize the dangers but I cherish the openness of scientific investigation too much to put up such a note. I stand by the distinction between knowledge of the world and how it is used. So I must say 'no' to Steiner's question. Provided, of course, that scientists fulfil their social obligations. The main reason is that the better understanding we have of the world the better chance we have of making a just society, the better chance we have of improving living conditions. One should not abandon the possibility of doing good by applying some scientific idea because one can also use it to do bad. All techniques can be abused and there is no knowledge or information that is not susceptible to manipulation for evil purposes. I can do terrible damage to someone with my glasses used as a weapon. Once one begins to censor the acquisition of reliable scientific knowledge, one is on the most slippery of slippery slopes.

To those who doubt whether the public or politicians are capable of taking the correct decisions in relation to science and its applications, I strongly commend the advice of Thomas Jefferson; 'I know no safe depository of the ultimate powers of the society but the people themselves, and if we think them not enlightened enough to exercise that control with a

wholesome discretion, the remedy is not to take it from them, but to inform their direction.'

But how does one ensure that the public are involved in decision making? How can we ensure that scientists, doctors, engineers, bioethicists and other experts, who must be involved, do not appropriate decision making for themselves? How do we ensure that scientists take on the social obligation of making the implications of their work public? We have to rely on the many institutions of a democratic society: parliament, a free and vigorous press, affected groups and the scientists themselves. That is why programmes for the public understanding of science are so important. Alas, we still do not know how best to do this. The law which deals with experiments on human embryos is a good model: there was wide public debate and finally a vote in the Commons leading to the setting up of the Human Embryology and Fertilization Authority.

At a time when the public are being urged and encouraged to learn more science, scientists are going to have to learn to understand more about public concerns and interact directly with the public. It is most important that they do not allow themselves to become the unquestioning tools of either government or industry. When the public are gene literate, the problems of genetic engineering will seem no different in principle from those such as euthanasia and abortion, since they will no longer be obfuscated by the fear that comes from the alienation due to ignorance.

REFERENCES

Basalla, G. 1988 *The evolution of technology.* Cambridge University Press.

Carey, J. 1995 *The Faber book of science*. London: Faber and Faber.

Dworkin, R. 1993 *Life's dominion*. London: Harper Collins.

Kevles, D. J. 1985 *In the name of eugenics*. Berkeley: University of California Press.

Muller-Hill, B. 1988 *Murderous science*. Oxford University Press.

Nuffield Council on Bioethics 1998 *Mental disorders and genetics: the ethical context*. London: Nuffield Council on Bioethics.

Rhodes, R. 1986 *The making of the atomic bomb*. New York: Simon & Schuster.

Wolpert, L. 1992 *The unnatural nature of science*. London: Faber and Faber.